Fundamental Noise-Limited Optical Phase Locking at Femtowatt Light Levels

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We describe an optical phase lock loop (PLL) designed to recover an optical carrier at powers below one picowatt in a Deep Space optical transponder. Previous low power optical phase lock has been reported with powers down to about 1 pW [1, 2]. We report the demonstration and characterization of the optical phase locking at femtowatt levels. We achieved a phase slip rate below one cycle–slip/second at powers down to 60 femtowatts. This phase slip rate corresponds to a frequency stability of 1×10^{-14} at 1 s, a value better than any frequency standard available today for measuring times equal to a typical two–way delay between Earth and Mars. The PLL shows very robust stability at these power levels. We developed simulation software to optimize parameters of the second order PLL loop in the presence of laser flicker frequency noise and white phase (photon) noise, and verified the software with a white phase noise model by Viterbi [3]. We also demonstrated precise Doppler tracking at femtowatt levels.

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